INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : A61C 7/00	**A1**	(11) International Publication Number: **WO 90/08512** (43) International Publication Date: 9 August 1990 (09.08.90)

(21) International Application Number: PCT/US90/00361

(22) International Filing Date: 24 January 1990 (24.01.90)

(30) Priority data:
301,606 24 January 1989 (24.01.89) US

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(81) Designated States: AT (European patent), AU, BE (European patent), BR, CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: A METHOD OF PRODUCING AN ORTHODONTIC BRACKET

(57) Abstract

A method for providing an orthodontic bracket for placement on a malocclused tooth in a patient's jaw to correct the malocclusion, comprises the steps of generating digitized information representative of the shape of the tooth and its location with respect to the jaw; using data processing equipment to generate a mathematical model of the tooth as located in the jaw, from the digitized data, and to calculate the finish position in the jaw to which the tooth is to be moved; determining the form of the bracket and its placement position on the tooth in order to move the tooth to the finish position in a selected course of orthodontic treatment; and providing the bracket of such form. A jig may also be provided to ensure correct placement of the bracket on the tooth.

A Method of Producing an Orthodontic Bracket

This invention relates to the provision of orthodontic brackets and like appliances.

Early in the history of orthondontics, dentists constructed their own applicances to treat patients. As the use of appliances grew, the orthodontic supply company became economically feasible. At first, all orthondontic brackets, or braces, whether produced by the doctor or supply company, were designed simply as handles to which the force-producing agents, most often archwires, were attached. Both the magnitudes and directions of orthodontic forces were controlled by placing appropriate bends in the archwires. See for example, Figures 1 and 3 of U.S. Patent No. 3,447,128.

The next major evolutionary step in appliance design was the "singular wire" concept. See, for example, Figures 2 and 4 to 19 of U.S. Patent No. 3,477,128. Force magnitudes were still determined by wire and not the brackets. However, force vector directions were transferred from the wire to the brackets. Bracket slots were cut so that the desired forces were applied to each tooth in the arch by simply ataching, fully ligating, a straight length of wire with rectangular cross-section into the bracket slots. Furthermore, different bracket base thicknesses were employed to control labial-lingual dental positioning. See, for example, U.S. Patent No. 3,660,900. These developments reduced considerably the amount of wire bending, and therefore, the length of time required by a dentist to treat a case. While such systems are generally considered to represent the state-of-the-art today, there remains a major disadvantage in the treatment mechanics of these products.

In the current "straight wire" systems, of which

there are several, all bracket force vectors for
specific tooth types (e.g., upper cuspids, upper central
incisors, lower first molars, etc.) are manufactured to
polulation averages. Thus there is no individual
adaptability in any given straight wire system. The
patient's specific pretreatment malocclusion, the
condition requiring treatment, dental surface
morphology, and facial type tend to be completely
disregarded, as are individualized treatment goals. It
is well known, however, that these factors influence the
selection of ideal mechanical parameters for every case.

Viewed from one aspect the invention provides a
method for producing an orthodontic bracket for
placement on a malocclused tooth in a patient's jaw to
correct the malocclusion, comprising the steps of
generating digitized information representative of the
shape of the tooth and its location with respect to the
jaw; using data processing equipment to generate a
mathematical model of the tooth as located in the jaw,
from the digitized data, and to calculate the finish
position in the jaw to which the tooth is to be moved;
determining the form of the bracket and its placement
position on the tooth in order to move the tooth to the
finish position in a selected course of orthodontic
treatment; and providing the bracket of such form.

Viewed from another aspect the invention provides a
method for determining orthodontic bracket placement on
a malocclused tooth in a subject's jaw to correct the
malocclusion, comprising the steps of generating digital
information defining the shape and location of the
malocclused tooth with respect to the patient's jaw;
generating a mathematical model of the malocclused
tooth as positioned in the jaw from the digitized
information; calculating the finish position in the jaw
to which the malocclused tooth is to be moved from the
digitized information; and calculating the placement
position of an orthodontic bracket on the malocclused

tooth required in order to move the malocclused tooth to
its finish position by a preselected orthodontic
treatment.

Viewed from a further aspect the invention provides
a method for determining orthodontic bracket placement
on a dental arch to correct a malocclusion, comprising
the steps of generating digital information defining the
shape and location of the teeth with respect to the
arch; generating a mathematical model of the teeth as
positioned in the arch from the digitized information;
calculating the finish position in the arch of the teeth
from the digitized information; and calculating the
placement position of orthodontic brackets on selected
teeth required in order to move malocclused teeth to
their finish positions by a preselected orthodontic
treatment.

Viewed from a still further aspect the invention
provides a method for determining orthodontic appliance
placement on at least one dental arch to correct
malocclusion between teeth in the arches, comprising the
steps of generating digital information defining the
shape and location of the teeth in each dental arch with
respect to the other dental arch; generating a
mathematical model of the arches as positioned in the
head from the digitized information; calculating the
finish position of the dental arches which is required
to correct the malocclusion from the digitized
information; and calculating the placement position of
an orthodontic appliance on at least one of the arches
required in order to correct the malocclusion by a
preselected orthodontic treatment.

Thus, in accordance with the invention it is
possible to have orthodontic applicance placement with
individualized parameters.

In carrying out the invention, and in accoradnce
with the particular method of subsequent orthodontic
treatment which has been selected to be used on the

patient by the practitioner, the correct position in which to place a bracket on the tooth to move the tooth to the finish position is calculated from the mathematical model and finish position which are determined. The correct bracket position is defined as that position which yields zero force in all directions, if, and only if, the subject tooth is in its ideal position with the archwire installed. Thus, when the brackets are subsequently placed and fixed in the patient's mouth, an archwire is placed on the bracket slots, and the archwire is fully ligated, the resultant individual force vectors will automatically move the teeth to the finish position.

The particular type of orthodontic bracket to be used in the method may be selected either before or after calculating its placement position on the tooth. In either event, in the preferred embodiments of the invention a standard bracket is thereafter modified, if desired, so as to provide for tooth movement to the finish position which has been determined individually for the patient, in view of the patient's physical deviations from the dental and skeletal statistical averages for an ideal finish position.

Precise fixation of the brackets at the prescribed location in the patient's mouth is necessary for the proper corrective forces to be achieved. A further step in the preferred embodiment of the invention is to calculate the shape of a positioning device, such as a bracket positioning jig, for the orthodontic appliance to provide for the positioning of the bracket on the tooth in precisely the calculated placement position, and then forming a positioning jig to conform to the shape of the jig so calculated. When the positioning jig with the bracket attached is placed over a patient's tooth, the bracket is automatically located at the precise position which will result in the required force vectors for treatment when attached to the tooth.

In the preferred embodiments the forces to effect treatment are produced by archwires. The archwires, when installed, act as springs which have been deflected by an amount proportional to the deviation of the tooth from its ideal location. An archwire, preformed in accordance with the requirements to move the affected tooth to its finish position when attached to the bracket, produces appropriate force magnitudes at various stages of treatment to move the tooth to its ideal position. An additional step in the preferred embodiments is thus the step of forming an archwire with respect to the mathematical model and the bracket into the configuration to cause to tooth to move to the calculated finish position when installed in the bracket on the tooth.

While normally the orthodontic treatment to be undertaken with brackets provided in accordance with the invention will contemplate realignment of the patient's teeth in one or both arches, or even one arch with respect to the other, the preferred method of bracket production, for purposes of clarity and brevity of description, will be described with respect to the repositioning of a single malocclused tooth.

The first step of the method is the generation of accurate digital information defining the shape and location of the malocclused tooth with respect to the patient's jaw. This information may be generated in a number of ways, such as electromechanically, by laser scanning, sonic ranging, digital video scanning or magnetically. Various devices which may be so utilized are described in Rekow, Computer Aided Design And Manufacture In Dentistry: A Review Of The State Of The Art, 58 The Journal of Prosthetic Dentistry 512 (1987). Sonic ranging devices of this type are described, for example, in U.S. Patent No. 3,821,469.

The second step of the preferred embodiment is the generation of a mathematical model, utilizing the

digitized information. The use of digitized information
to generate mathmetical models is well known in the
Computer-Aided Design ("CAD") art, and need not be
described at the present time in view of the state of
the art. It should be noted that each of the three
systems described in the Rekow article previously
referred to uses CAD.

The mathematical model may be as detailed as the
particular circumstances require, dependent only upon
the quantity of dititized information generated in the
prior step. Thus, in many applications of the preferred
embodiment, a complete "model-", as that term is used in
the dental art to refer to a full replication of the
upper and lower dental arches and associated jaw
structure, will be mathematically generated. A physical
embodiment of such a model is shown, for example, in
Figure 1 of U.S. Patent No. 2,467,432.

The next step is the calculation of the "finish"
position of the malocclused tooth or teeth, with respect
to their positions in the mathematical model. Movement
to the finish position typically may involve "tipping",
that is, movement toward or away from adjacent teeth,
"torquing", that is, angulating toward or away from the
center of the mouth, and "rotation", that is, rotary
movement of the tooth about its longitudinal axis,
intrusional-extrusional or bodily movement.

There are a number of methods of treatment commonly
used by the orthodontist. Each method takes different
factors into account with varying degrees of emphasis.
For the purposes of the preferred embodiment the
orthodontist provides a description of the desired
results, which is prescribed for reaching the finish
position of each individual tooth relative to adjacent
teeth, opposing teeth, supporting bony foundations and
soft tissue, and the entire cranial-facial complex.
Utilizing standard statistical tooth position data, the
repoisitioning of the teeth is calculated to provide a

methematical model of the finish position. In the prior
art, a similar step was accomplished manually in order
to account for individual tooth morphology by physically
removing duplicated teth from a model and repositioning
them in a new model in the finish position. See for
example, Figure 3 above in the above referenced U.S.
Patent No. 2,467,432. However this procedure did not
take into account the individual finish position desired
relative to the cranial-facial base.

In the preferred method, this repositioning is done
mathematically by appropriate software programs which
may be derived by conventional means for the particular
method of treatment elected by the orthodontist. An
"ideal" finish position is not based upon statistical
averages and takes into account the variation and
physical characteristics of the individual patient.
Therefore, it is preferably that, the program be
utilized to provide a customized finish position for the
particular patient, so as to make the finish position
ideal forthe patient, rather than attempting to have the
patient duplicate the statistically average finish
position.

After the finish position for the teeth in question
has been calculated, the placement position of the
orthodontic appliance, a bracket, for example, is
calculated. In the presently preferred embodiment, a
straight wire technique is utilized. The bracket
manufacturers provide positioning information
recommendations as to their brackets in the ideal
position. This information is utilized together with
the mathematical model of the finish position to
calculate the bracket placement position on the teeth.

While it is possible to position the brackets on
the teeth in a variety of methods, in the preferred
embodiment there is carried out the step of calculating
the shape of a bracket positioning jig from the
mathematical model in order to ensure that the bracket

is accurately placed. A large variety of positioning
jigs are known in the art, and such devices extend from
rather simple direct application devices, such as is
shown in U.S. Patent No. 3,686,762 to complex devices
such as are shown in U.S. Patent Nos. 4,160,322,
4,183,141 and 4,360,341, which conform in shape to and
overlay the tooth itself. In its broadest sense, the
term "bracket positioning jig" as used herein includes
devices utilized in the "indirect" method of bracket
application, such as is described in U.S. Patent No.
4,160,322, to position simultaneously a plurality of
brackets on the patients teeth. Thus, after the
particular form of jig has been selected, the shape of
the jig required to place the bracket or brackets in the
previously calculated placement position or positions is
calculated. Thereafter, in the preferred embodiment,
the next step of the present invention is to form the
positioning jig calculated in the previous step.

In as much as the mathematical model of the arch
has been calculated in the preferred embodiment, another
step which may be utilized is the preforming of an
archwire for attachment to the bracket to conform to the
orthodontic treatment to be undertaken. The particular
details as to shape, size, and the like of the archwire
are matters of choice of the orthodontist, depending
upon the particular treatment and brackets involved. and
normally on the subject of specification in the
prescription,if the step is to be undertaken.

Orthodontic brackets are generally manufactured in
standard types in accordance with population averages.
One method of creating individualized brackets is to cut
custom bracket slots for each patient. The cost of that
procedure is usually prohibitive. The computerized
design method, according to the present embodiment
utilizes modification of the angulation of the
bracket/tooth interface on an individualized basis in
order to cause the bracket to produce a desired force

vector on the tooth. Specific force vectors are
prescribed, and an entire system or brackets/adhesive
placement, pre-formed archwires, and peripheral
appliances (head gear, elastics, etc.) is selected, if
so desired.

In some instances a particular bracket may be
selected and, for the particular case, modified in
certain respects before calculating its placement
position. In such an instance, the placement position
is calculated for modified form of the bracket. In
other instances, a selected bracket may, after
calculation of its placement position, be determined to
require modification in order to be placed in the
required placement position. In such an instance, the
bracket may be modified after calculation of the
placement position to prevent its placement in
accordance therewith.

In the method of the preferred embodiment, standard
brackets are modified as appropriate to produce the
required treatment force vectors by use of a structural
adhesive system. The modification of standard brackets
by use of a structural adhesive system is known in the
art. The structural adhesive is initially a moldable
putty which easily take on the contour of the dental
surface to which the appliance will be fixed, and which
provides the interface between that surface and the
bracket base. A premachined archwire slot in the
bracket face can thus be oriented with aix axes of
freedom with respect to the dental surface so as to
incorporate precisely the required force vectors. In
practicing one embodiment the bracket is correctly
positioned on a laboratory model of the tooth, and the
adhesive is hardened to a rigid state by a irradiation
with ultravoilet light, followed by oven post-cure. The
adhesive is then an inseparable, integral part of the
bracket, now customized for thatpatient's individual
tooth.

While the use of a moldable putty to interface between the bracket and the tooth is satisfactory, the present method may be utilized in conjunction with computer-aided design and computer-aided manufacture (CAD/CAM), as described in the Rekow article referred to above, to provide a machined or cast base conforming to the tooth morphology and containing an appropriately positioned bracket receiving recess or fitting, so as to permit the base to be fixed to either the bracket or the tooth. The other of the two is then fixed to the base, thereby simplifying the attachment of the bracket to the tooth and its customized ideal position for the individual patient. By this method, standard brackets are readily adapted to customized use, so as to simplify the inventory retirements of the practitioner. Additionally, such customized brackets may be provided to the practitioner by a dental laboratory, where the digitized information is utilized in the process of providing the practitioner with the required dental appliances for the correction of the malocclusion.

As will be apparent, the practice of the present invention may be restricted to a single tooth, may be utilized with some or all of the teeth in a given dental arch, or utilized with teeth in both of the arches of the patient. Therefore, while the description of a prefered embodiment has been in certain instances, with respect to a single tooth for purposes of brevity and clarity, the practice of the invention is not so limited.

Furthermore, the present invention may also be utilized with respect to orthodontic diagnoses involving the requirement of movement of one arch, in its entirety, with respect to the other, as where the patient exhibits a lateral offset. In such an instance, a mathematical model is calculated for both arches in their relative positions with respect to one another. The prefered embodiments will take into account the

relative resistance to movement of various teeth or groups of teeth. Bracket positions can then be customized to accountfor these forces. Indications can be provided for the inter-dental arch force mechanics in order to correct or maintain the position of each individual arch over its respective jaw structure as well as relative to the opposing arch and jaw.

It will be appreciated that modifications to the methods set forth herein may be made by those skilled in the art.

CLAIMS

1.   A method for producing an orthodontic bracket for placement on a malocclused tooth in a patient's jaw to correct the malocclusion, comprising the steps of generating digitized information representative of the shape of the tooth and its location with respect to the jaw; using data processing equipment to generate a mathematical model of the tooth as located in the jaw, from the digitized data, and to calculate the finish position in the jaw to which the tooth is to be moved; determining the form of the bracket and its placement position on the tooth in order to move the tooth to the finish position in a selected course of orthodontic treatment; and providing the bracket of such form.

2.   A method as claimed in claim 1, wherein the form of the bracket is determined before its placement position is determined.

3.   A method as claimed in claim 1, wherein the form of the bracket is determined after its placement position is determined.

4.   A method as claimed in claim 1, 2, or 3, wherein the bracket has an initial shape, selected from standard shapes, that is modified to the determined form.

5.   A method as claimed in any preceding claim, including the provision of means for enabling the correct placement of the bracket on the tooth.

6.   A method as claimed in any claim 5, including the steps of determining the shape of, and providing, a jig to ensure correct placement of the bracket on the tooth.

7.   A method as claimed in any preceding claim,

including the steps of determining the shape of, and providing, a preformed archwire for use with the bracket.

8. A method as claimed in any preceding claim, wherein the digitised information is generated for a plurality of teeth positioned in a dental arch, and a plurality of brackets are provided, each of whose form and placement position on a respective tooth is determined to achieve movement of the tooth to a respective finish position.

9. A method as claimed in claim 8, wherein digitised information is also generated for the other dental arch.

10. A method for determining orthodontic bracket placement on a malocclused tooth in a subject's jaw to correct the malocclusion, comprising the steps of generating digital information defining the shape and location of the malocclused tooth with respect to the patient's jaw; generating a mathematical model of the malocclused tooth as positioned in the jaw from the digitized information; calculating the finish position in the jaw to which the malocclused tooth is to be moved from the digitized information; and calculating the placement position of an orthodontic bracket on the malocclused tooth required in order to move the malocclused tooth to its finish position by a preselected orthodontic treatment.

11. A method for determining orthodontic bracket placement on a dental arch to correct a malocclusion, comprising the steps of generating digital information defining the shape and location of the teeth with respect to the arch; generating a mathematical model of the teeth as positioned in the arch from the digitized information; calculating the finish position in the arch of the teeth from the digitized information; and

calculating the placement position of orthodontic
brackets on selected teeth required in order to move
malocclused teeth to their finish positions by a
preselected orthodontic treatment.

12.   A method for determining orthodontic appliance
placement on at least one dental arch to correct
malocclusion between teeth in the arches, comprising the
steps of generating digital information defining the
shape and location of the teeth in each dental arch with
respect to the other dental arch; generating a
mathematical model of the arches as positioned in the
head from the digitized information; calculating the
finish position of the dental arches which is required
to correct the malocclusion from the digitized
information; and calculating the placement position of
an orthodontic appliance on at least one of the arches
required in order to correct the malocclusion by a
preselected orthodontic treatment.

INTERNATIONAL SEARCH REPORT

International Application No   PCT/US 90/00361

II. FIELDS SEARCHED

Minimum Documentation Searched ⁷	
Classification System	Classification Symbols
IPC⁵	A 61 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included In the Fields Searched ⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹

Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US, A, 4663720 (DURET) 5 May 1987 see the whole document --	1,4
A	EP, A1, 0025911 (HEITLINGER) 1 April 1981 see abstract --	1
A	EP, A1, 0091876 (DURET) 19 October 1983 see abstract --	1
A	Proceedings of the 38th Annual Conference on Engineering in Medicine and Biology, 30 September - 2 October 1985, Chicago, Illinois, volume 27, The Alliance for Engineering in Medicine and Biology, Publishers, (Washington, D.C., US), E.D. Rekow et al.: "CAD/CAM in dentistry", page 298 ---------	1,4

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
10th May 1990	13. 06. 90
International Searching Authority	Signature of Authorized Officer
EUROPEAN PATENT OFFICE	

Form PCT/ISA/210 (second sheet) (January 1985)

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 12/06/90
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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